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The Relationship between the Change in Pelvic Alignment during Moderate-Intensity Running and the Subjective Rating of Perceived Exertion, Rating of Perceived Exertion for Legs and Gluteus Muscles Fatigue in Female Novice and Recreational Runners

Hathaipat Tippayut[1], Pasakorn Watanatada[1,2] and Sompol Sanguanrungsirikul[1,2,3,*]

[1]*Sports Medicine Program, Faculty of Medicine, Chulalongkorn University, Bangkok 10330, Thailand*
[2]*Department of Physiology, Faculty of Medicine, Chulalongkorn University, Bangkok 10330, Thailand*
[3]*King Chulalongkorn Memorial Hospital, Bangkok 10330, Thailand*

([*]Corresponding author's e-mail: fmedssk@yahoo.com)

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Abstract

Running has become 1 of the 2 most well-known exercises for health; however, running may cause injuries. The purpose of this analytical descriptive study was to examine the occurrence of pelvic drop during moderate-intensity running in female novice and recreational runners; as well as investigating the relationship between the change in pelvic alignment and Rating of Perceived Exertion (RPE), Rating of Perceived Exertion for Legs (RPE_{legs}) and Gluteus muscles fatigue in novice and recreational runners. The participants, aged between 18 and 35 years old, comprised 27 novice runners (less than 1 year of running experience) and 27 recreational runners (2 - 4 years running experience). The participants in both groups performed the maximal oxygen uptake (VO_{2max}) test and ran at a self-selected speed on a treadmill for 30 min at moderate-intensity within the specified heart rate range of 40 - 59 % heart rate reserve (HRR). RPE, RPE_{legs} and sEMG were collected every 2 min and the pelvic kinematic data were also recorded every minute during the 30 min treadmill running test. The data were analyzed with a statistical significance level at p-value < 0.05. The results demonstrated that the time in starting pelvic drop was 8.15 ± 5.07 and 18.37 ± 6.70 min in female novice and recreational runner groups, respectively ($p < 0.01$). Pearson's correlations showed relationship between the pelvic alignment and RPE in novice runners (r = 0.47, $p < 0.01$) and recreational runners (r = 0.39, $p < 0.01$). Besides, Pearson's correlations showed relationship between the pelvic alignment and RPE_{legs} in novice runners (r = 0.48, $p < 0.01$) and recreational runners (r = 0.32, $p < 0.01$). In both groups, there was no relationship between the pelvic alignment and Gluteus medius and Gluteus maximus muscle fatigue. According to the study, the occurrence of a pelvic drop in novice runners was faster than recreational runners. The study indicated that consideration of RPE and RPE_{legs} variables might be beneficial for female runners and future studies.

Keywords: Pelvic drop, Pelvic alignment, Moderate-intensity running

Introduction

Nowadays, there are various types of exercise that have gained popularity among numerous people. Running has become 1 of the 2 most well-known exercises for health, along with walking [1]. One reason running has gained popularity among female novice runners and recreational runners is because it prevents chronic diseases such as cardio and vascular diseases [2,3].

American College of Sports Medicine recommends exercise at moderate intensity for 30 - 60 min, 5 days per week, to improve health [4]. However, running may cause injuries in which the incidence of Running-Related injuries varies between 11 - 85 % or 2.5 - 38 injuries per 1,000 h [5]. In addition, various studies stated that the risk factors that cause major injuries are listed as follows: Increasing BMI, previous injuries, running frequency, increased the running intensity, training errors and sex [5-8].

As well as the risk factors, female runners have been reported to have more injuries than male runners [7,8]. The injured runners experienced knee and lower leg injuries, [7,8] diagnosed as iliotibial band syndrome, patellofemoral pain, Achilles tendon pathology and tibial or fibular stress fractures [9]. Furthermore, running biomechanics factors should be considered in order to prevent Running-Related injuries [10,11] and the increase of the pelvic drop.

Pelvic drop is one of the risk factors related to hip abductors muscle strength [12] which may cause more risk to lower extremity injuries [9,13,14]. Novice runners injuries are commonly caused by an increasing degree of a pelvic drop, which is an effect of the hip muscles weakness. This condition is often discovered from gluteus medius during the stance phase of running; initial foot-ground contact to toe-off [12,15].

Gluteus medius is the primary stabilizer of the hip in the frontal and transverse planes [16,17]. According to previous studies, running athletes who had strong hip muscles pelvic drop between 2.15 - 4 ° during running [12,18,19]. In comparison, recreational runner pelvic drop between 7.57 - 10.94 ° and tend to increase the degree of the pelvic drop when running time past [20].

Some studies reported the knee adduction moment (KAM) is likely greater if the pelvic drop increases more than 4 °. In addition, it is stated that every 1 ° increase of the pelvic drop changes will have an 80 % or 1.8 times greater risk of soft tissue injury such as patellofemoral pain (PFP), Achilles tendinopathy (AT), medial tibial stress syndrome (MTSS) and iliotibial band syndrome (ITBS) [16,19]. Furthermore, an increased drop in pelvic was reported to be associated with metabolic energy demands which effected running economy [20]. Moreover, the previous study found that runners with more experience would likely have a lower injury rate than runners with less experience or novice runners [21].

Thus, the purpose of this study was to examine the occurrence of pelvic drop during moderate-intensity running in female novice and recreational runners; as well as, investigate the relationship between the change in pelvic alignment and RPE, RPE_{legs} and Gluteus muscles fatigue in female novice and recreational runners. The results of this study might be considered for female runners and future studies.

Materials and methods

Participants

The participants (aged 18 - 35 years old, Body mass Index; BMI 18.5 - 24.9 kg/m^2) comprised 27 novice runners (less than 1 year of running experience) and 27 recreational runners (2 - 4 years running experience). According to previous study, the majority of runners are in this age range [22].

All participants were healthy, with no history of cardiopulmonary problems and neuromuscular impairment. Participants in both groups ran at least 3 days per week but recreational runners ran a minimum distance of 8 km per week.

The exclusion criteria of both groups were 1) a history of the lower limb and lower back injuries in the past 6 months, 2) a history of lower limb abnormalities or lower limb surgery, and 3) different leg lengths of more than 5 mm [23].

The participants who passed all criteria underwent VO_{2max} test and self-selected speed running on a treadmill for 30 min at moderate-intensity within the specified heart rate range of 40 - 59 % HRR. Each test was scheduled at least 48 h apart.

The participants were volunteers. In accordance with the Institutional Review Board, Faculty of Medicine, Chulalongkorn University (IRB No.687/61), analytical descriptive study method approval was obtained.

Procedures

During the first visit, researchers introduced the content of the research and obtained consent forms from the participants. The participants were asked to refrain from caffeine, alcohol and exercise 48 h before each test and asked to eat 3 h prior to the test. All participants ran in the same pair of their personal running shoes for all tests.

VO_{2max} test (modified Bruce protocol)

The test began with a 3 min warm-up at a speed 2.7 km/h on treadmill (Nautilus T518LC, USA) and increased speed and incline every 3 min until exhaustion occurred. During the tests, oxygen consumption (Jaeger, Oxycon mobile, Germany), heart rate (HR) (Polar Heart Rate Chest Strap T31, Polar Electro Inc, USA), RPE (Borg's 6 - 20 scale) [24] and RPE_{legs} [25,26] were recorded (**Figure 1**).

Self-selected speed running protocol

The test began with a 3 min warm-up on the treadmill. Each participant ran at a self- selected speed for 30 min at moderate-intensity within the specified heart rate range of 40 - 59 % heart rate reserve (HRR). RPE (fatigue in whole body), RPE_{legs} (fatigue in the legs) and sEMG were collected every 2 min. Additionally, during the 30-min treadmill running test with no incline, the pelvic kinematic data was also recorded once a minute. Moreover, heart rate data was collected to confirm runners were exercising at moderate-intensity.

Figure 1 The maximal oxygen uptake (VO_{2max}) test.

Oxygen uptake data collection

Oxygen uptake was collected using the Gas Analyzer system with software version 5.3.0 (Oxycon mobile, Jaeger Germany) every 2 min during the self-selected speed running protocol.

Kinematic data collection

A 5 infrared camera (100 Hz) Qualisys motion capture system (Qualisys AB, Sweden) with Qualisys motion capture system software (version 2.7) captured pelvic kinematics (posterior superior iliac spines; PSIS) (**Figure 2**). Kinematic data were collected for 10 s every minute. The average magnitude of change in pelvic alignment more than 4 ° from baseline (at time 0) was the cutoff point (pelvic drop) and that minute was considered for analysis. Pelvic alignment was calculated as the angle between the left and right PSIS relative to a horizontal line.

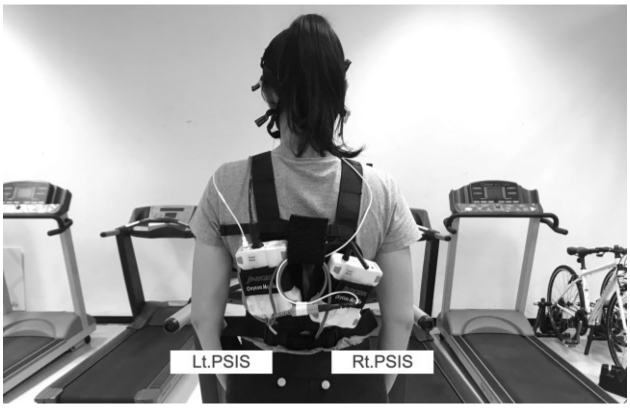

Figure 2 The reflective markers were placed bilaterally on posterior superior iliac spines (PSIS).

Surface electromyography data collection

Muscle activity data were collected for 10 s every 2 min by Surface electromyography (Delsys, USA) with 1,000 and filtered from 20 to 200 Hz in EMGworks Analysis program. The maximum amplitude of Gluteus muscle activity was identified for each running gait cycle and calculated for the 10 s block. Surface Electrode placement was placed at Gluteus medius: Between Iliac crest and Greater trochanter tubercle and Gluteus maximus muscles: Between Greater trochanter tubercle and Sacral vertebrae.

Muscle fatigue analysis

According to previous studies, muscle fatigue was indicated by the rate of fatigue from the slope of regression line of the median frequency graph [20,27,28]. If the value is negative, it indicates muscle fatigue in hertz per minute (Hz/min).

Statistical analysis

The data were analyzed using the statistical package for social science (SPSS), version 22.0 for Mac. The unpaired t-test was used to test for differences in time to start pelvic drop between novice and recreational runners. Pearson's correlation was used to test for the relationship between the change in pelvic alignment and RPE, RPE_{legs} and Gluteus muscles fatigue. Statistical significance was accepted for all tests at $p < 0.05$. All data were presented as mean ± SD.

Results and discussion

Results

The characteristics of the female novice and recreational runners are shown in **Table 1**.

Table 1 The characteristics of female novice (N = 27) and recreational runners (N = 27) mean ± SD.

	Novice runners (N = 27)	**Recreational runners (N = 27)**	***p*-value**
Age (years)	28.63 ± 4.16	30.59 ± 2.93	0.05
Weight (kg)	53.12 ± 6.14	52.20 ± 5.22	0.56
Height (cm)	158.78 ± 5.72	160.67 ± 5.70	0.23
BMI (kg/m^2)	21.03 ± 1.74	20.19 ± 1.29	0.05
The true leg length (cm)	81.24 ± 3.46	81.96 ± 3.38	0.44
The apparent leg length (cm)	89.30 ± 3.22	90.44 ± 4.10	0.26
Running experience (months)	7.67 ± 3.92	31.93 ± 8.50	< 0.01*
Mileage (km/week)	14.57 ± 9.69	37.44 ± 17.55	< 0.01*
VO_{2max} (mL/kg/min)	27.19 ± 3.57	33.38 ± 4.12	< 0.01*

*Statistical significance at *p*-value < 0.05

Figure 3 shows the heart rate range of 40 - 59 % HRR (The VO_2 uptake range of 3 - 7.1 METs) during 30 min of moderate-intensity running of female novice and recreational runners, respectively.

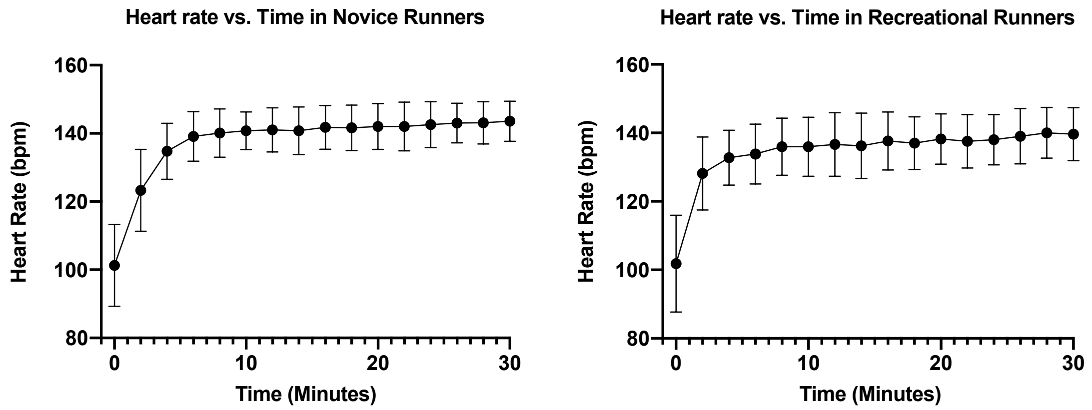

Figure 3 Heart rate vs. time in novice (N = 27) and recreational runners (N = 27).

The average time of pelvic drop occurrence between female novice and recreational runners (novice runners; 8.15 ± 5.07 min vs. recreational runners; 18.37 ± 6.70 min, $p < 0.01$) are shown in **Table 2**. In addition, the unpaired t-test reveals that there was a statistically significant difference between groups. Pelvic drop is defined as the change in a pelvic alignment greater than 4 ° from the start.

Table 2 Time of occurrence of pelvic drop between novice (N = 27) and recreational runners (N = 27) (mean ± SD).

	Novice runners (N = 27)	Recreational runners (N = 27)	*p*-value
Time (min)	8.15 ± 5.07	18.37 ± 6.70	< 0.01*

*Statistical significance at *p*-value < 0.05

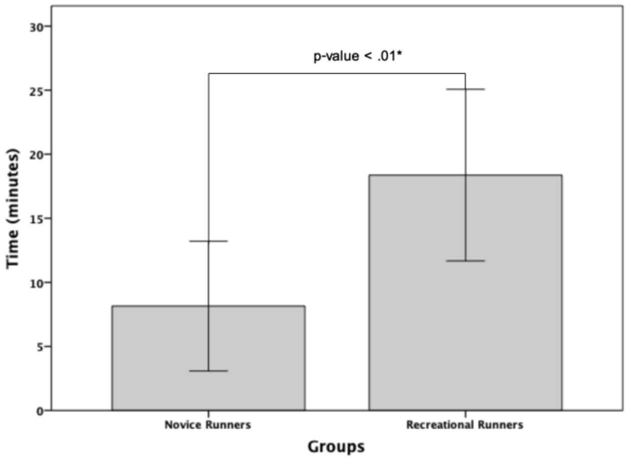

Figure 4 Time of occurrence of pelvic drop between novice (N = 27) and recreational runners (N = 27).

Pearson's correlation showed a relationship between the change in pelvic alignment and RPE in novice runners (r = 0.47, $p < 0.01$) and recreational runners (r = 0.39, $p < 0.01$) (**Table 3**).

Table 3 Pearson correlation coefficient (r) for the relation of the pelvic alignment and RPE in novice (N = 27) and recreational runners (N = 27).

	Novice runners (N = 27)		Recreational runners (N = 27)	
	Pearson correlation	***p*-value**	**Pearson correlation**	***p*-value**
RPE	0.47	< 0.01*	0.39	< 0.01*

*Statistical significance at *p*-value < 0.05

Figure 5 and **6** show the correlation between the change in pelvic alignment and RPE in novice and recreational runners, respectively.

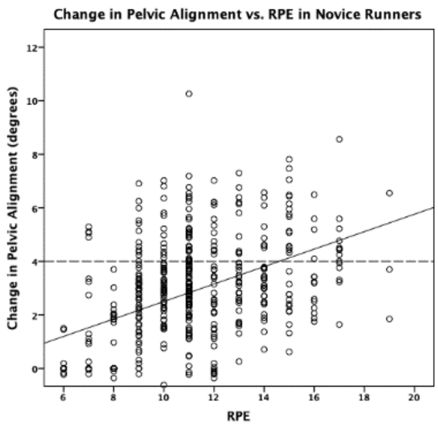

Figure 5 Correlation between the change in pelvic alignment and RPE in novice runners.

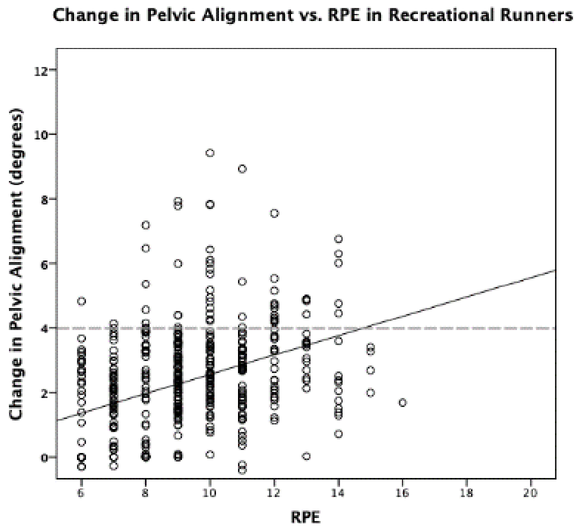

Figure 6 Correlation between the change in pelvic alignment and RPE in recreational runners.

Pearson's correlation showed a relationship between the change in pelvic alignment and RPE_{legs} in novice runners (r = 0.48, $p < 0.01$) and recreational runners (r = 0.32, $p < 0.01$) (**Table 4**).

Table 4 Pearson correlation coefficient (r) for the relation of the change in pelvic alignment and RPE_{legs} in novice (N = 27) and recreational runners (N = 27).

	Novice runners (N = 27)		Recreational runners (N = 27)	
	Pearson correlation	***p*-value**	**Pearson correlation**	***p*-value**
RPE_{legs}	0.48	< 0.01*	0.32	< 0.01*

*Statistical significance at *p*-value < 0.05

Figures 7 and **8** show the correlation between the change in pelvic alignment and RPE in novice and recreational runners, respectively.

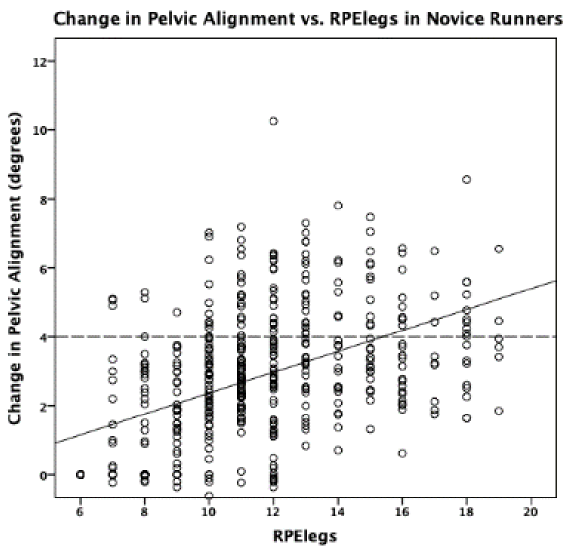

Figure 7 Correlation between the change in pelvic alignment and RPE_{legs} in novice runners.

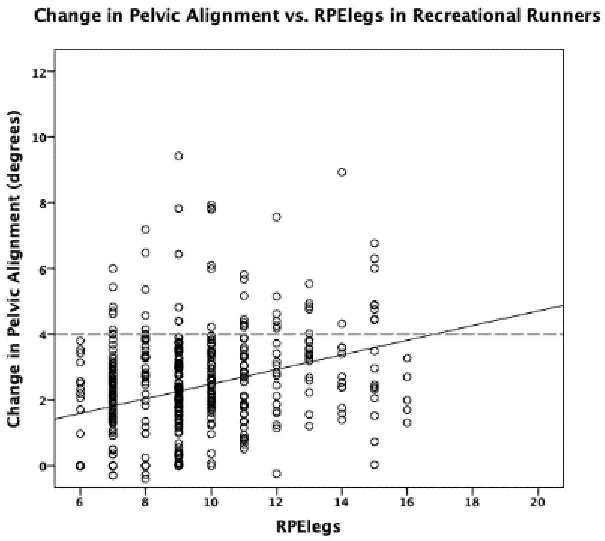

Figure 8 Correlation between the change in pelvic alignment and RPE_{legs} in recreational runners.

Table 5 Pearson correlation coefficient (r) for the relation of the change in pelvic alignment and Gluteus medius muscle fatigue in novice (N = 27) and recreational runners (N = 27).

	Novice runners (N = 27)		Recreational runners (N = 27)	
	Pearson correlation	***p*-value**	**Pearson correlation**	***p*-value**
Gluteus medius muscle fatigue	0.15	0.04*	0.05	< 0.50

*Statistical significance at *p*-value < 0.05

Figures 9 and **10** show the correlation between the change in pelvic alignment and Gluteus medius muscle fatigue in novice runners and recreational runners, respectively.

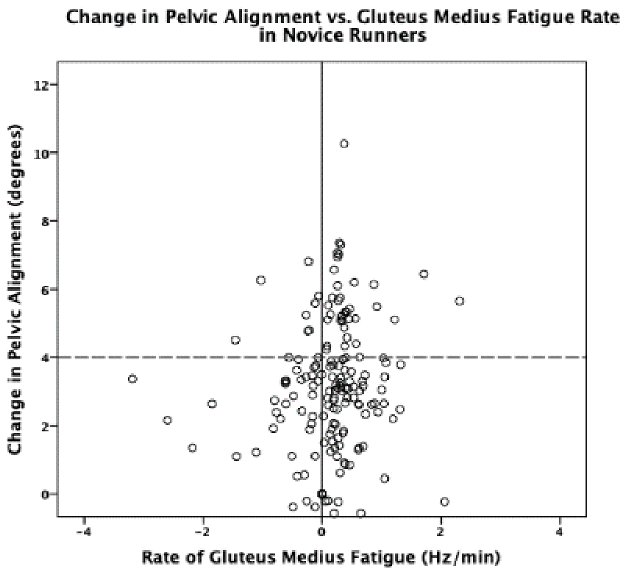

Figure 9 Correlation between the change in pelvic alignment and Gluteus medius muscle fatigue in novice runners.

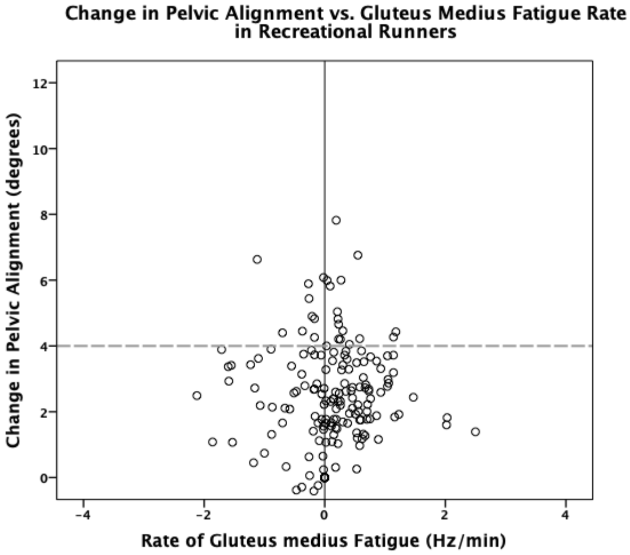

Figure 10 Correlation between the change in pelvic alignment and Gluteus medius muscle fatigue in recreational runners.

Table 6 Pearson correlation coefficient (r) for the relation of the change in pelvic alignment and Gluteus maximus muscle fatigue in novice (N = 27) and recreational runners (N = 27).

	Novice runners (N = 27)		**Recreational runners (N = 27)**	
	Pearson correlation	***p*-value**	**Pearson correlation**	***p*-value**
Gluteus maximus muscle fatigue	0.21	< 0.01*	−0.01	0.88

*Statistical significance at *p*-value < 0.05

Figures 11 and 1**2** show the correlation between the change in pelvic alignment and Gluteus maximus muscle fatigue in novice runners and recreational runners, respectively.

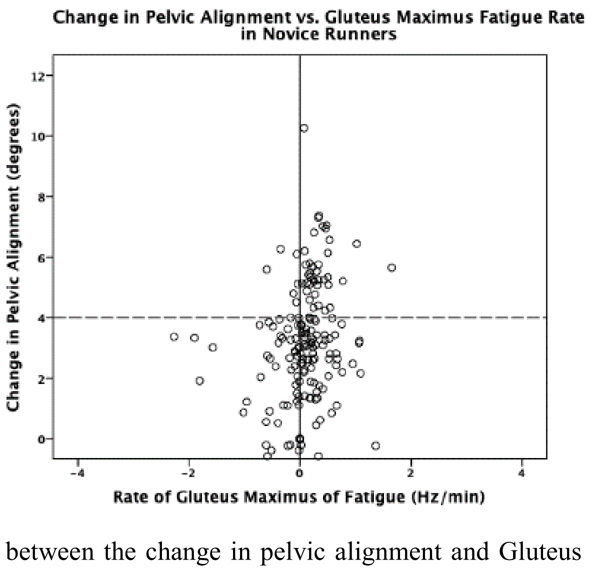

Figure 11 Correlation between the change in pelvic alignment and Gluteus maximus muscle fatigue in novice runners.

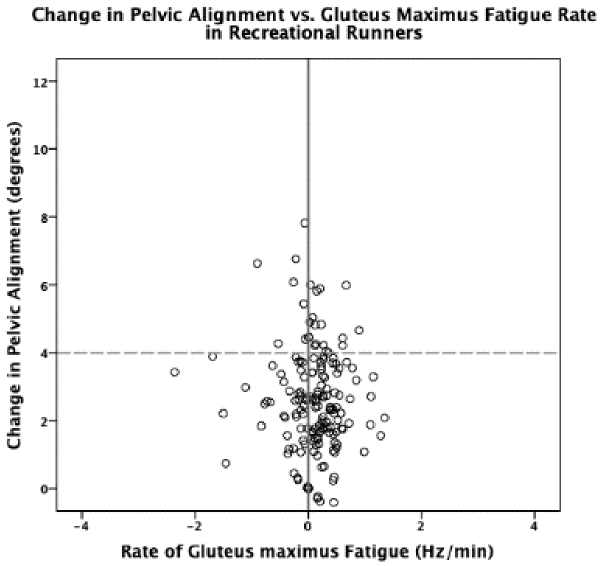

Figure 12 Correlation between the change in pelvic alignment and Gluteus maximus muscle fatigue in recreational runners.

Discussion

The objectives of this study were to examine the occurrence of pelvic drop during moderate-intensity running in female novice and recreational runners; as well as, to investigate the relationship between the change in pelvic alignment and RPE, RPE_{legs} and Gluteus muscles fatigue in female novice and recreational runners. The present study found that the occurrence of pelvic drop in female novice runners was faster than female recreational runners (novice runners; 8.15 ± 5.07 min vs. recreational runners; 18.37 ± 6.70 min, $p < 0.01$). This finding was similar to a previous study that examined the time in starting pelvic drop in male and female recreational runners during a 30-min self-selected speed treadmill running test (18.75 ± 7.25 min) [20, 29].

According to this study, when considering age, weight, height, BMI, true leg length and apparent leg length of female novice runners, there were no differences from recreational runners except running experience and mileage from inclusion criteria. All runners in both groups performed the VO_{2max} test which showed the maximum ability of the cardiovascular system, respiratory system, gas exchange and muscular system. The results showed that the VO_{2max} of recreational runners was significantly higher than the novice runners. This finding was similar to the previous study which indicated the relationship between VO_{2max} and training volume (mileage) [30].

Pelvic drop is one of the risk factors related to hip abductors muscle strength [12] which may cause more risk of lower extremity injuries [9, 13, 14]. Injuries in novice runners are frequently caused by an increasing degree of pelvic drop, which is a result of weak hip muscles. Runners with more experience would likely have a lower injury rate than runners with less experience or novice runners [21]. This finding may indicate that recommending weight training exercises to improve the hip muscle strength in beginner runners or untrained runners may be beneficial. Moreover, this may suggest that untrained runners should alternate between walking and running.

The RPE scale is a simple tool that allows a person to estimate exercise intensity and is easy to use. The positive correlation showed that the higher the RPE and RPE_{legs}, the greater the change in pelvic alignment. The individual data showed that when RPE reached 12 - 13 and RPE_{legs} reached 13 - 14, the pelvic drop occurred in around 90 % of runners. Although RPE was a subjective measurement, there was a high correlation between RPE and heart rate during exercise (r = 0.62 - 0.90) [31]. According to a previous study, RPE is also correlated to muscle fatigue [32, 33]. It is possible that when the runners increase the intensity or speed of running, the pelvic drop would occur faster because of muscle fatigue. Therefore, runners should control or decrease the speed to maintain the pelvic alignment during running. These variables could be considered and might be beneficial for future studies.

In the present study, there was no relationship between the pelvic alignment and Gluteus medius and Gluteus maximus muscle fatigue in both groups. However, the individual data showed that there were

Gluteus medius muscle fatigue in 4 runners (15 %) and Gluteus maximus muscle fatigue in 7 runners (26 %) among female novice runners. Besides, the individual data showed that there was Gluteus medius muscle fatigue in 8 runners (30 %) and Gluteus maximus muscle fatigue in 8 runners (30 %) among female recreational runners. Participants might have adapted the technique prior to fatigue.

The previous study evidenced Gluteus medius muscle isometric strength was a poor predictor of pelvic drop [29]. It suggested that future studies should investigate the relationship between clinical-based dynamic strength measures and pelvic drop. Although there was no relationship between isometric strength and pelvic drop, hip and trunk muscle strength training reduced pelvic drop excursion in women [34].

The limitation of this study is moderate-intensity running within the specified heart rate range in female novice and recreational runners. Future studies may want to consider using more than one intensity or different groups of runners and could try to determine how other muscles affect pelvic alignment and running biomechanics. In addition, the strength of gluteus muscles; as well as, other muscles that are associated with pelvic alignment should be considered.

Conclusions

The occurrence of pelvic drop in female novice runners was faster than female recreational runners. There was a relationship between the change in pelvic alignment and RPE and also RPE_{legs} in female novice and recreational runners. As a result, consideration of these variables might be beneficial for female runners and future studies.

Acknowledgements

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